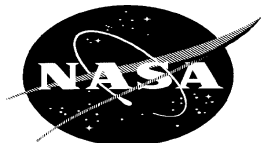# Geostationary Operational Environmental Satellite (GOES)

GOES-R Series

Solar Imaging Suite (SIS)

Performance and Operational Requirements Document (PORD)

DRAFT
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National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

1 Scope

1.1 Identification

This Performance and Operational Requirements Document (PORD) sets forth the performance requirements for the National Oceanic and Atmospheric Administration (NOAA) Solar Imaging Suite (SIS). The SIS PORD establishes the allocation of the system requirements to the SIS and defines the instrument requirements.

1.2 Mission Review

The SIS objectives are as follows:

-Measure the magnitude of solar X-ray flux.

-Determine the solar EUV flux from 5 to 129 nm.

- Locate coronal holes for forecasts of recurring geomagnetic activity.

- Locate flares for forecasts of solar energetic particle events.

- Assess active region complexity for flare forecasts.

- Determine occurrence of coronal mass ejections (CME's) and CME width, extent, velocity, and mass (or relative brightness.

The SIS instruments provide data to the Ground System, designated as SIS-GS in this document, via the spacecraft communication system. The SIS-GS takes the SIS data, spacecraft telemetry data, orbit determination data and other required information and autonomously generates products for the NOAA users. This requirements document only applies to the SIS instruments, but the SIS contractor must have an understanding of the total system to assure that the SIS-GS will be able to provide the required data.

1.3 Document Overview

1.3.1 Conflicts

In the event of conflict between the referenced documents and the contents of this SIS PORD, the contents of the SIS PORD shall be the superseding requirements.

In the event of a conflict involving the external interface requirements, or in the event of any other unresolved conflict, the NASA contracting officer shall determine the order of precedence.

1.3.2 Requirement Weighting Factors

The requirements stated in this SIS PORD are not of equal importance or weight. The following paragraphs define the weighting factors incorporated in this document.

- Shall designates the most important weighting level; that is, mandatory. Any deviations from these contractually imposed mandatory requirements require the approval of the NASA contracting officer.

- Will designates a lower weighting level. These will requirements designate the intent of the Government and are often stated as examples of acceptable designs, items, and practices. Unless required by other contract provisions, noncompliance with the will requirements does not require approval of the NASA contracting officer and does not require documented technical substantiation.

- May designates the lowest weighting level, possibility, or discretion of the Government or contractor.

1.3.3 Definitions

Throughout this document, the following definitions apply:

Accuracy: Refers to the error in a measurement, that is the difference between the measurement result and the object to be measured (the measured or true value). It includes both systematic and random errors. Systematic errors must be estimated from an analysis of the experimental conditions and techniques. Random errors can be determined, and reduced, through repeated measurements under identical conditions and a Standard Deviation calculated. The magnitude of a random error shall be taken as three standard deviations (3σ).

All requirements/all performance requirements/all operational requirements: Refers to any performance characteristic or requirement in the GIRD, SIS PORD or the SIS Unique Instrument Interface Requirements Document (SIS UIID).

B/B_{SUN}: Ratio of the image brightness to the mean brightness of the solar disk

Cadence: The time interval between the start of successive data collection sequences.

Data Latency: The time interval between the end of a data collection sequence and the time that the data is available at the spacecraft interface.

Detector sample or element: Refers to the output of a physical detector after the Analog-to-Digital (A/D) converter and Time Delay and Integration (TDI) processing, if required.

Eclipse: Defined as when the solar disk is completely or partially occulted by the Earth or Moon as viewed from the spacecraft.

Extended Solar X-ray Imager (ESXI): GOES R Solar X-ray Imager referred to in this document as the SXI

Flux Resolution: Minimum difference in flux which can be measured; usually determined by the Analog-to-Digital Converter.

Full Disk: Defined as 42 arc-min diameter - 1.3 times the visible solar diameter

Fully Functional Configuration: Being able to collect the full complement of science data; determine instrument response changes; acquisition of sensor health and status data; generation of sensor, calibration, monitoring, health and status data streams; and reception and execution of command and control data.

Launch: The period of time between lift off and the separation of the GOES-R series satellite from the launch vehicle. The duration of launch is expected to be less than 2 hours long.

Measurement Resolution: Resolution of the A/D converter.

Pixel: Applies to calibrated and navigated data samples (after resampling during the ground processing if required).

Objective: A requirement that is desireable to to achieve as closely as possible.

Precision: Refers to the standard deviation (1σ) of a statistically meaningful number of samples of a measurement.

Resolution: Ability to distinguish two adjacent features in the spectral, spatial or temporal domain.

Scanline: Refers to any line of pixels that extends in an East-West direction across the Sun or space in the format of GOES SIS data.

Threshold: A requirement which must be met.

Transfer Orbit: The sequence of events that transpires to establish the GOES R series satellite on-station after the GOES-R series satellite has separated from the launch vehicle.

1.3.4 Requirement Applicability

All requirements apply over the entire life of the SIS. All requirements in this SIS PORD apply to data after all ground processing except as indicated.

2 Applicable Documents

Various parts of this requirement document refer to some of these documents.

NOAA's Mission Requirements Document 1A (MRD-1A) for the GOES-R Series, Version 1.0 dated July 11, 2003.

General Interface Requirements Document, NASA-GSFC, Document Number 417-R-GIRD-0009 dated June 2003

Unique Instrument Interface Requirements Document (UIID), NASA-GSFC, Document Number 417-R-UIIDSIS-0034, TBS

3 SIS Pointing Requirements

3.1 Instrument Pointing Requirements

The following sections define the pointing requirements for the individual instruments in the SIS. The instruments shall be coaligned on a common platform. Pointing supplied by the spacecraft at the interface of the platform to the spacecraft is defined in the UIID. All instrument pointing knowledge shall be provided with the same latency as required by the instrument data.

3.1.1 SXI Pointing Requirements

3.1.1.1 Pointing Accuracy

Under normal operation the SXI line of sight shall be pointed to within ±3 arc-min, 3σ, of the Sun center.

3.1.1.2 Pointing Stability

The line of sight pointing shall not drift during an exposure (~20 seconds) more than ±2 arc-sec, 3σ, (Goal: ±1 arc-sec) and not more than ±1 arc-min over a 24-hour period.

3.1.1.3 Pointing Knowledge

The line of sight pointing knowledge of the SXI shall be ±2.5 arcseconds, 3σ.

3.1.2 Extreme Ultraviolet Sensor (EUVS) and X-Ray Sensor (XRS) Pointing Requirements

3.1.2.1 Pointing Knowledge

During normal operation, the knowledge of the XRS and EUVS boresight pointing with respect to the sun center shall be ±2 arcminutes, 3σ, with a measurement precision of ±1 arcminute when the sun center is within ±2º of the lines of sight of the instruments.

4 SIS Sensor Requirements

The following requirements apply to all instruments of the SIS.

Each instrument shall operate independently.

4.1 SIS Operational Modes

All SIS Instrument Modes and their function shall be documented in the Interface Control Document (ICD).

The SIS Instruments shall execute ground commands to individually enable and disable each autonomous function.

Each SIS Instrument shall initiate all commanded mode transitions within10 seconds after receipt of command.

Each instrument shall have an autonomous Safe Mode to be used if an anomalous condition is detected.

Transitions to Safe Mode, whether commanded or autonomous, shall require no more than 1 second to initiate.

Transition from Safe Mode to Normal Operational Mode shall not exceed 10 minutes.

4.1.1 Normal Operational Mode

The SIS instruments shall implement a Normal Operational Mode. In Normal Operational Mode, the SIS instruments shall be in a fully functional configuration.

4.1.2 On-orbit Storage Mode

In the On-orbit Storage State, the SIS instruments shall be in a configuration that provides health and safety telemetry to the spacecraft and provides protection to the entrance aperture from contamination and micrometeorites.

4.1.3 Instrument Diagnostic State

Each SIS Instrument shall implement an Instrument Diagnostic State. In Instrument Diagnostic State the instrument shall be in a fully functional configuration and have as a minimum have the following capabilities:

- Send data from all detectors.

- Send the same data both compressed and uncompressed to allow ground evaluation of the impact of compression on the data.

- Send all bits from the A/D converter.

- Perform electronic in-flight calibration.

In all of the above requirements, the data channels to be sent to the spacecraft will be selected to stay within the allocated data rate. The acquisition of this data shall be done in a manner that does not require any design modification of the focal planes and their readout systems from their nominal design.

4.2 On-Orbit Operations

The SIS will conduct regular operations, i.e., Normal Operational Mode, while flying aboard a 3-axis stabilized, geostationary spacecraft with orbital limit constraints as stated in the General Interface Requirements Document (GIRD) and/or the SIS Unique Interface Document (UIID).

The SXI shall be capable of interrupting current operations by command and starting the acquisition of a new image observation sequence after a new image sequence upload, within 30 seconds. If they are powered down to conserve spacecraft power they shall be capable of returning to full operations within 10 minutes after power is applied.

The science data stream shall contain a data-valid/not-valid flag.

4.2.1 Eclipse

The SIS shall be fully functional through eclipse periods.

4.2.2 Operations After Maneuvers

4.2.2.1 Yaw Flip
The SIS instruments shall be able to operate in a spacecraft yaw flip mode. The spacecraft contractor is required to provide the capability to perform a biannual flip about the yaw axis, where the yaw axis is defined as the nadir-pointing axis, such that the nominal north face of the spacecraft points south.

4.2.2.2 Station Keeping

The SIS instruments shall meet all requirements within 10 minutes after the spacecraft interface has returned to being within specification following spacecraft station keeping maneuvers.

4.3 Post On-orbit Storage Activation

The SIS instruments shall meet all requirements within 1 day of instrument turn-on after post storage activation.

4.4 Lifetime

The SIS instruments shall have a minimum operational lifetime of 10 years after a maximum of 5 years on orbit storage and after a maximum of 5 years of ground storage. The Mean Mission Duration (MMD), namely the integrated area under the reliability versus time curve, for the instrument shall be 8.4 years with a reliability of 0.6.

4.5 On-Board Processors (OBP)

4.5.1 Commandability of Redundant On-Board Processor Configuration

The operational configuration of OBP redundant components shall be commandable and configurable from the ground. *Rationale: On-Board Processors refers to the CPU, RAM, ROM, NV-RAM, clocks, component interface and monitor circuitry such as temperature, voltage, and current sensors.*

4.5.2 Flight Load Non-volatile Memory

The entire flight software image shall be contained in non-volatile memory at launch.

4.5.3 Ground Commandable OBP Reboot/Reinitialization

The OBP shall provide for reset by ground command of software for recovery from instrument anomalies, including software anomalies.

4.5.4 Deterministic Power-on Configuration

The OBP shall initialize upon power-up into a predetermined configuration.

4.5.5 Failsafe Recovery Mode

The SIS instruments shall provide a failsafe recovery mode dependant on a minimal hardware configuration that is capable of accepting and processing a minimal command subset sufficient to load and dump memory.

In failsafe recovery mode the SIS instruments shall be commandable to begin execution at a specified memory address.

4.6 Flight Software

4.6.1 Language and Methodology

All software developed for the SIS instruments shall be developed with ANSI/ISO standard languages and a widely-accepted, industry-standard, formal software design methodology. Minimal use of processor-specific assembly language is permitted for certain low-level programs such as interrupt service routines and device drivers with NASA approval.

4.6.2 Software Module Upload

The flight software shall be reprogrammable on-orbit to allow for new versions of software segments and table values to be loaded from the ground without computer restart.

The flight software shall be capable of being uploaded in modules, units, segments, and objects which shall be usable immediately after completion of an upload of the modified modules, units, segments, and objects.

Activation of the modified modules, units, segments, and objects shall not require completion of an upload of the entire flight software image.
Rationale: Software should be patchable without having to replace the entire image.

4.6.3 Flexibility and Ease of Software Modification

The SIS flight software design shall be flexible and table-driven for ease of operation and modification.

The SIS flight software shall be rigid in terms of scheduling and prioritization of critical processing tasks to ensure their timely completion.

All software data that are modifiable and examinable by ground operators shall be organized into tables that can be referenced by table number so table data can be loaded and dumped by the ground without reference to memory address.
Rationale: G*round software and databases should not need to change when data are relocated by a recompilation of the flight software.*

The definition of instrument commands within the ground database shall not be dependent on physical memory addresses within the flight software.
Rationale: All commands processed by the flight software (with the exception of loads and dumps by address) should be interpreted by the flight software without the use of any uploaded physical address. Existing command definitions in the database should be unaffected when the flight software is recompiled.

4.6.4 Version Identifiers in Embedded Code

All software and firmware versions shall be implemented with an internal identifier (embedded in the executive program) that can be included in the instrument engineering data.

This software identifier shall be keyed to the configuration management process so that the exact version of software and firmware residing in the instrument can be determined at any time.

4.6.5 Flight Processor Resource Sizing

During development, flight processors providing computing resources for instrument subsystems shall be sized for worst case utilization not to exceed the capacity shown below (measured as a percentage of total available resource capacity):

Flight Processor Resource Utilization Limits

	S/W PDR	S/W CDR	S/W AR
RAM Memory	40%	50%	60%

ROM Memory	50%	60%	70%
CPU	40%	50%	60%

4.6.6 Software Event Logging

The flight software shall include time-tagged event logging in telemetry.

The event messages shall capture all anomalous events, redundancy management switching of instrument components, and important system performance events.

All flight software components shall utilize a common format for event messages.

The flight software shall provide a means for ground command to enable and disable queueing of individual event messages.

The flight software shall buffer a minimum of 1000 event messages while the event messages are queued for telemetering to the ground.

The event message queue shall be configurable by ground command to either (a) discard the new events, or (b) overwrite oldest events when the queue is full.

The flight software shall maintain counters for:
the total number of event messages generated
 the number of event messages discarded because of queue overflow
the number of event messages not queued due to being disabled.

4.6.7 Warm Restart

The flight software shall provide a restart by ground command with preservation of the event message queue and memory tables.

4.6.8 Memory Tests

The flight software shall provide a mechanism to verify the contents of all memory areas.

4.6.9 Memory Location Dump Capability

The flight software, and associated on-board computer hardware, shall provide the capability to dump any location of on-board memory to the ground upon command.

The flight software memory dump capability shall not disturb normal operations and instrument data processing.

4.6.10 Telemetry

Telemetry points sampled by the instrument shall be controlled by an on-orbit modifiable table.

The sample rate of every instrument telemetry point shall be controlled by an on-orbit modifiable table.

4.7 Mechanical

Each instrument unit structure shall possess sufficient strength, rigidity and other characteristics required to survive the critical loading conditions that exist within the envelope of handling and mission requirements.

4.7.1 Design and Test Factors of Safety

The instrument contractor shall use the prototype factors of safety specified in NASA-STD-5001 for analysis and verification of structural units not containing beryllium.

The instrument contractor shall use a proof test factor, yield and ultimate factors of safety of 1.4, 1.45 and 1.6 respectively for structural elements containing beryllium.

4.7.2 Design Limit Loads

The structure shall be capable of withstanding all limit loads without loss of any required function.
Rationale: Limit loads are defined as all worst case load conditions including temperature effects from the environments expected during all phases of the structure's service life including manufacturing, ground handling, transportation, environmental testing, integration, pre-launch, launch and on-orbit operations and storage.

4.7.3 Non-Linear Loads

The flight unit structures shall be capable of withstanding redistribution of internal and external loads resulting from any non-linear effects including deflections under load.

4.7.4 Yield Strength

The flight unit structures shall be able to support yield loads without detrimental permanent deformation.
Rationale: Strength requirements are specified in terms of yield and ultimate loads. Yield loads are limit loads multiplied by prescribed factors of safety.

While subjected to any operational load up to yield operational loads, the resulting deformation shall not interfere with the operation of the instrument flight unit. .

4.7.5 Ultimate Strength

The unit structures shall be able to support ultimate loads without failure for at least 3 seconds including ultimate deflections and ultimate deformations of the flight unit structures and their boundaries. However, when proof of strength is shown by dynamic tests simulating actual load conditions, the 3-second limit does not apply.

Rationale: *Strength requirements are specified in terms of yield and ultimate loads. Ultimate loads are limit loads multiplied by prescribed factors of safety.*

4.7.6 Structural Stiffness

Stiffness of the flight unit structures and their attachments shall be designed by consideration of their performance requirements and their handling, transportation and launch environments.

Special stowage provisions shall be used if required to prevent excessive dynamic amplification during handling, transportation and transient flight events.

4.7.7 Unit Stiffness

The fundamental resonant frequency of an instrument flight unit shall be 50 Hz (TBR) or greater when the flight unit is constrained at its spacecraft interface.

4.7.8 Material Properties

Material properties shall be based on sufficient tests of the material meeting approved specifications to establish design values on a statistical basis.

Design values shall account for the probability of structural failures and loss of any required function due to material variability.

The instrument contractor shall specify the source and statistical basis of all material properties used in the design.

The effects of temperature on design values shall be considered.

4.7.9 Critical Members Design Values

For critical members, design values shall be selected to assure strength with a minimum of 99 percent probability and 95 percent confidence.

Structural members are classified as critical when their failure would result in loss of structural integrity of the flight units.

4.7.10 Redundant Members Design Values

For redundant members, design values shall be selected to assure strength with a minimum of 90 percent probability and 95 percent confidence.

Structural members are classified as redundant when their failure would result in the redistribution of applied loads to other structural members without loss of structural integrity.

4.7.11 Selective Design Values

As an exception to Sections "Critical Members Design Values" and "Redundant Members Design Values", greater design values may be used if a representative portion of the material used in the structural member is tested before use to determine that the actual strength properties of that particular structural member will equal or exceed those used in the design.

4.7.12 Structural Reliability

The strength, detailed design, and fabrication of the structure shall prevent any critical failure due to fatigue, corrosion, manufacturing defects and fracture throughout the life of the instrument resulting in the loss of any mission objective.

Accounting for the presence of stress concentrations and the growth of undetectable flaws, the instrument flight unit structures shall withstand loads equivalent to four complete service lifetimes.

While subjected to any flight operational load up to limit flight operational loads, the resulting deformation of the residual instrument flight unit structures shall not interfere with the operation of the instrument flight unit..

After any load up to limit loads, the resulting permanent deformation of the residual instrument flight unit structures shall not interfere with the operation of the instrument flight unit.

4.7.13 Mechanisms

Deployment, sensor, pointing, drive, separation mechanisms and other moving mechanical assemblies may be designed using MIL-A-83577B and NASA TP-1999-206988.

All instrument mechanisms shall meet performance requirements while operating in an earth gravity environment with any orientation of the gravity vector(TBR).

Moving mechanical assemblies shall have torque and force ratios per section 2.4.5.3 of GEV-SE using a NASA approved classification of each instrument mechanism.

For all operating points of the actuators, all rotational actuators shall have available a continuous maximum torque output greater than 7.0 milli-Newton meters.

For all operating points of the actuators, all linear actuators shall have available a continuous maximum force output greater than 0.28 N.

For mechanisms using closed-loop control, gain and phase margins shall be greater than 12 dB, and greater than 40 degrees, respectively.   The margins shall include the effects of the dynamic properties of any flexible structure.

All instrument mechanisms requiring restraint during launch shall be caged during launch without requiring power to maintain the caged condition.

All instrument mechanisms requiring restraint shall be released from a caged condition by command.

All instrument mechanisms requiring restraint shall be returned to a caged condition ready for launch by either command or by manual actuation of an accessible caging device.

4.7.14 Magnetic

The instrument shall not have uncompensated magnetic moment greater than 0.0005 ampere-turn meter-square per kilogram of mass (TBR).

4.7.15 Pressurized Units

Instruments with pressurized systems shall follow the requirements in accordance with EWR-127-1 and MIL-STD-1522A for the design of pressurized systems.

The instrument shall have no open fluid reservoirs when delivered to the spacecraft contractor.

4.8 Thermal - Design and Construction Standards

4.8.1 Temperature Limits

The instrument contractor shall establish Mission Allowable Temperatures (MAT) for the instrument with at least 5° C of analytical/test uncertainty.
Rationale: Thermal margin is defined as the temperature delta between MAT versus the bounding predictions plus analytical uncertainty.

Figure 3.4.2.1.1 Temperature Requirement Graphic

TBS

The instrument shall maintain thermally independent units and their internal components within Mission Allowable Temperatures (MAT) limits during all flight operational conditions including bounding worst-case environments.

4.8.2 Outgassing Temperature Requirements

The instrument shall maintain the thermally independent units and their internal components within Out-gassing Allowable Temperatures (OAT) during all out-gassing procedures.

4.8.3 Non Operational Temperature Requirements - NOT

The Non-Operational Temperatures (NOT) range shall extend at least 20° C warmer than the hot MAT and at least 20° C colder than the cold MAT.

The cold Non-Operational Temperature shall be -25° C or colder.

4.8.4 Thermal Control Hardware

There shall be two or more serial and independent controls for disabling any heater where any failed on condition would cause over-temperature conditions or exceed the instrument power budget.
Rationale: Independent controls include thermostats, relays and other switches.

The instrument heaters shall be sized to have 25% margin for worst case conditions.

When the instrument is off, instrument survival heaters shall maintain independent unit temperatures above non-operational limits.
Rationale: The only intended use of survival heaters willl be to maintain non-operational temperatures when the instrument is off.

Instrument survival heaters shall be thermostatically controlled.

4.9 Multi-Layer Insulation

Multilayer insulation (MLI) shall have provisions for venting and electrical grounding to prevent Electro-Static Discharge (ESD).

5 SXI Sensor Requirements

5.1 Sensor Definition

5.1.1 SXI Overview and Description

The SXI is a coronal imager capable of operating in the soft X-ray to EUV wavelength range (henceforth referred to as the XUV range). It provides full-disk solar images at high cadence around the clock except for brief periods during an eclipse. Available combinations of exposures and filters allows the coverage of the entire dynamic range of solar X-ray features, from coronal holes to X-class flares, as well as the estimate of temperature and emission measure. The operational goals are to: locate coronal holes for geomagnetic storm forecasts, detect and locate flares for forecasts of solar energetic particle events related to flares, monitor changes in the corona that indicate coronal mass ejections (CMEs) detect active regions beyond east limb for F10.7 forecasts, and analyze active region complexity for flare forecasts.

5.2 Field of View

The SXI shall acquire full spatial resolution data from all spectral channels.

The field of view (FOV) shall be 42.0 arc-min by 42.0-arc-min minimum and shall have square picture elements (pixels) of a size that supports the point response described below.

5.3 Point Response

The sampled data output from the image when illuminated by a point source shall meet the requirements stated in the following table over the instrument's measurement range and spectral range. The table below describes the percentage of the total energy from the X-ray source that falls within a circular area of a given diameter for those pixels which are in their linear response range. Demonstration of this requirement can be accomplished by use of multiple exposures if necessary to accommodate signal-to-noise and dynamic range. The specification is at the system level and therefore includes all optical and detection components. Point response shall be uniform to ±30% (Goal ±10%) across the entire field of view.

Point Response Requirement in Terms of Encircled Energy

Encircled Energy	Threshold Diameter (arc sec)	Goal Diameter (arc sec)
37%	7	5
66%	14	10
75%	21	15
85%	35	25
100% (TBS)	56	40

5.4 System Spectral Response

The physical coronal parameters to be remotely sensed by SXI are representations of the plasma temperature and emission measure. Specifically the objective is to provide intensity measurements in a set of wavelength

ranges that most effectively allow retrieval of the so-called Differential Emission Measure (DEM) defined below. The DEM reconstruction shall be performed as defined below to the uncertainties specified in the following table.

	Coronal Hole		Quiet Corona		Active Region		Flare	
T	**DEM**	**Error**	**DEM**	**Error**	**DEM**	**Error**	**DEM**	**Error**
5.5	20.29	±0.342	20.30	±0.342	20.50	±0.342	21.70	±0.342
5.6	20.33	±0.301	20.20	±0.301	20.40	±0.301	21.70	±0.301
5.7	20.36	±0.255	20.20	±0.255	20.40	±0.255	21.70	±0.255
5.8	20.36	±0.204	20.30	±0.204	20.50	±0.204	21.70	±0.204
5.9	20.32	±0.146	20.40	±0.146	20.60	±0.146	21.75	±0.146
6.0	20.28	±0.146	20.70	±0.079	20.80	±0.079	21.80	±0.079
6.1	20.20	±0.146	20.90	±0.079	21.00	±0.079	21.90	±0.079
6.2	20.00	±0.146	20.80	±0.079	21.20	±0.079	22.00	±0.079
6.3	19.70	±0.204	20.50	±0.079	21.30	±0.079	22.10	±0.079
6.4	19.20	±0.255	20.10	±0.079	21.30	±0.079	22.25	±0.079
6.5	18.50	±0.301	19.70	±0.146	21.10	±0.079	22.40	±0.079
6.6	N/A	N/A	19.20	±0.204	20.80	±0.079	22.55	±0.079
6.7	N/A	N/A	18.60	±0.255	20.30	±01.46	22.70	±0.079
6.8	N/A	N/A	N/A	N/A	19.50	±0.204	22.95	±0.079
6.9	N/A	N/A	N/A	N/A	18.50	±0.255	23.15	±0.079
7.0	N/A	N/A	N/A	N/A	N/A	N/A	23.20	±0.079
7.1	N/A	N/A	N/A	N/A	N/A	N/A	23.15	±0.146
7.2	N/A	N/A	N/A	N/A	N/A	N/A	22.95	±0.204
7.3	N/A	N/A	N/A	N/A	N/A	N/A	22.65	±0.255
7.4	N/A	N/A	N/A	N/A	N/A	N/A	22.10	±0.301
7.5	N/A	N/A	N/A	N/A	N/A	N/A	21.50	±0.342

Model Differential Emission Measures for Solar Features (See Note)

(Left margin rotated labels: **Objective**, **Threshold**)

Note: Base 10 logarithmic values of parameters are given.

DEFINITIONS:

Temperature
Temperature is defined in units of Kelvins. The Table gives the base 10 logarithmic value of the temperature grid for DEM evaluation. The grid is evenly spaced in the logarithmic domain. The threshold range covers T = 1 to 10 MK ($\mathrm{Log}_{10}(T)$=6.0 to 7.0). The goal range covers from T = 0.5 to 20 MK ($\mathrm{Log}_{10}(T)$=5.7 to 7.3). Grid bins may be considered to be evenly spaced in the logarithmic domain, e.g., the bin centered on $\mathrm{Log}_{10}(T)$=6.5 would begin at $\mathrm{Log}_{10}(T)$=6.45 and end at $\mathrm{Log}_{10}(T)$=6.55.

Differential Emission Measure
The differential emission measure used in this SISPORD is the column emission measure per unit temperature as defined by:

$$DEM_C = \int \frac{n_e^2}{dT} dx$$

where n_e^2 is the electron number density in units of cm^{-3}, dT is the temperature differential in units of Kelvins (K), x is the line of sight integration path in units of cm. Thus, DEM_C has units of cm^{-5}-K^{-1}. Integration of

DEM_C over temperature yields the column emission measure. The Table gives the base 10 logarithmic value of the *DEM_C* to be evaluated on the temperature grid given.

Error

The error allowable in the final retrieval of DEM information is per pixel and is defined in terms of a multiplicative error factor, e.g., a 20% error represents an error factor of 1.2. The base 10 logarithm of this error factor is given in the Table. For an error factor of 1.2, we have Log_{10}(Error)=0.079, which is *additive* in the logarithmic domain. For example, if $Log_{10}(DEM_C)$=21.5 ±0.146, then the uncertainty of the final DEM determination is allowed to range from $Log_{10}(DEM_C)$=21.354 to 21.646.

5.4.1 Out-of-Band Response

Out-of-band response from IR, visible, UV, EUV and/or X-ray radiation and in-band stray radiation shall be minimized as needed to meet DEM reconstruction (spectral response) requirements. In addition a means of tracking unplanned out-of-band signal, e.g., that due to a filter failure, shall be provided.

5.4.2 Spatial Response Uniformity

The image shall be correctable so that when illuminated by a uniform source from a single exposure the calibrated telemetered image shall not vary by more than 5% across the field of view.

5.4.3 Photometric Resolution

The SXI shall be capable of providing a photometric resolution of at least 0.1% of the instrument's single exposure full-scale data output for radiances greater than 20 times the instrument's minimum detectable radiance.

The transfer function between the X-ray photon flux entering the instrument and the data output for each image pixel shall be a monotonic function of intensity from a monochromatic X-ray source.

5.4.4 Scattered Light and/or Blooming

Over single raw data image exposure of the detector by a point source with an incident flux exceeding the instrument full-scale response by a factor of 10^4 at the exposure used shall not cause the reported flux of a pixel TBS arc-sec away from the point source image to increase by more than 20%.

5.5 Photometric Accuracy and Precision

5.5.1 Accuracy and Precision

The SXI shall measure radiance to an accuracy of ±20% (Goal: ±10%). Temperature shall be measured with an accuracy of ±10% (Goal: ±5%) (TBS).

5.5.2 Stability

The accuracy of photometric products shall not vary by more than +/-5% over a 24-hour period.

5.5.3 Photometric Gain Stability Over Temperature

The photometric gain of the SXI shall not change by more than TBS over the operating temperature range of the instrument.

5.5.4 Defective Pixels

The SXI processed data shall have less than 0.1% defective pixels. No more than one tenth of the defective pixels shall be adjacent. A defective pixel is one that is not compliant with any single requirement listed in this PORD.

5.5.5 In-Flight Calibration

The SXI shall include a ground-commandable internal illumination source that can be used on-orbit, during pre-launch testing, and during spacecraft integration and test to verify the integrity of the detector and associated electronics. As a goal it should provide information to normalize the gain of the system (flat fielding).

An electrical calibration signal of requirement TBD shall be inserted as close to the detector output signal as practical in the electronics chain.

Means for close coordination between spacecraft and instrument operations shall be provided in order to support cooperative calibration procedures, e.g., a 'fast' slew of the instrument by the spacecraft or platform to provide flat-field response information.

Means for close coordination between spacecraft, instrument and external operations shall be provided in order to support external/ground truth calibration procedures, eg. rocket under flight calibration.

5.6 Temporal Resolution

5.6.1 Single Spectral Passband

Full field-of-view, full spatial resolution images of the Sun, in a given spectral passband, shall be obtained and telemetered with a frequency such that a composite image product covering the entire photometric measurement range can be constructed every two minutes (goal: every minute) under normal operations.

5.6.2 Multiple Spectral Passbands

Emission measure distribution as a function of temperature requires measurements in a minimum of three spectral passbands. Full field-of-view, full spatial resolution images of the Sun, in a minimum of three spectral passbands, shall be obtained and telemetered with a frequency such that a derived emission measure distribution image product covering the entire photometric measurement range can be constructed every six minutes (goal: every three minutes) under normal operations.

5.6.3 Data Latency

Data latency, from the completion of image integration to the transmission of the last image bit to the spacecraft data bus, shall be no more than 10 seconds.

5.7 Data and Control Capability

5.7.1 Partial Image Readout

The SXI shall be capable of providing partial images of the FOV via partial detector readout. The center and size of this partial readout region shall be configurable. An on-board memory table will be provided such that the location and size of the partial readout can be loaded as a function of time to account for feature motion with solar rotation.

5.7.2 Data Compression

The SXI shall be able to provide pixel data in at least one lossless and at least one 'lossy' compression mode in addition to being able to provide the full, uncompressed data values.

5.7.3 Binning and Summing of Pixels

The SXI shall be capable of both on-chip binning and post-readout summing of pixels.

5.7.4 Automatic Bright Region Location and Tracking

The SXI shall implement an algorithm to determine the pixel centroid locations of up to the five brightest region locations for each exposure taken, depending on ground commanded intensity and minimum-number-of-pixels thresholds for bright region identification.

The SXI shall be configurable by ground command to take partial images centered on any or all of the five bright regions automatically identified.

5.7.5 Automatic Flare Location and Tracking

The SXI shall implement an algorithm to determine the pixel centroid location of a single flaring region for each exposure taken, depending on ground commanded intensity and minimum-number-of-pixels thresholds for bright region identification. The thresholds for flare location shall be independent of those for bright region location.

The SXI shall be configurable by ground command to automatically transition to a different flare-imaging sequence that may take different whole disk images or may take partial images centered on the flare region automatically identified.

5.7.6 Image Summary Metadata

The SXI shall provide image metadata, defined as summary information about each exposure, prior to the completion of image telemetry. The information shall include, but not be limited to: flare location and summary information, bright region location and summary information, and image histogram information.

6 XRS Requirements

6.1 XRS Overview and Description

The GOES X-ray Sensor (XRS) is the primary measure of and standard for solar flare magnitude. Its primary function is to provide a means of detecting the beginning, duration, and magnitude of solar X-ray flares.   Many space weather phenomena are preceded by a solar event such as a solar flare. In addition, the XRS is used as an input for the empirical model of Solar Energetic Proton events that can have severe impacts on satellites and

astronauts. Two X-ray channels are required to monitor the disk-integrated solar fluxes in the 0.05 to 0.8 nm wavelength range at 3-second intervals. The sensor shall be sensitive enough to permit quiet sun background measurements at low levels of solar activity as well as very large solar flares. For calculations of threshold sensitivity, a $2x10^6$K solar spectrum such as the one presented by "Mewe and Groenshild, 1981, Astron. Astrophys. Suppl, Ser., vol 45, pp11-52" shall be assumed.

6.2 Spectral Bands

The XRS shall have two bands covering the spectral range of 0.05 to 0.8 nm. The two bands shall be XRS-A: 0.05 – 0.4 nm and XRS-B: 0.1-0.8 nm.

6.3 Minimum and Maximum Flux

The minimum flux measurable by the XRS-A channel shall be less than 5×10^{-9} W m^{-2} (Goal: 1×10^{-9} Wm^{-2}) and the maximum flux shall be greater than 5×10^{-4} Wm^{-2} (Goal: 1×10^{-3} Wm^{-2}).The minimum flux measurable by the XRS-B shall be less than 2×10^{-8} W m^{-2} (Goal: 1×10^{-9} Wm^{-2}) and the maximum flux shall be greater than 2×10^{-3} Wm^{-2} (Goal: 4×10^{-2} Wm^{-2}).

6.4 Out of Band Rejection

The out-of-band rejection shall be such that < 10% of the observed signal comes from out-of-band for a typical solar spectrum or some method of monitoring the out-of-band single shall be provided.

6.5 Long-term Stability

Over the duration of the mission, the XRS instrument response shall change by less than 5% or a method of tracking changes shall be provided.

6.6 Flux Resolution and Response

For the two X-ray channels, the resolution of the energy flux measurements shall be < 2% (Goal: ±1%) of the detected flux for fluxes > 20 times the minimum measurable fluxes specified in paragraph 6.3. The telemetered data shall be a monotonic function of the input fluxes with deviations from a monotonic response function being less than ±2%.

6.7 Wavelength Response

The wavelength response for each of the two XRS channels shall be within ±25% of the previous GOES XRS instruments between the defined wavelengths (see tables). The wavelength response of each channel shall be

measured to an accuracy of ±5%. The instrument shall be calibrated at sufficient wavelengths to adequately characterize the wavelength response from each detector component with a wavelength-dependent response. An analysis of the uncertainties and errors of each component shall be provided to verify that the number of calibration wavelengths is sufficient to adequately characterize the relative wavelength response to an accuracy of ±5%.

Table   XRS Wavelength Response

Relative wavelength response of the two XRS channels as a function of wavelength. The upper and lower limits are acceptable ranges of relative sensitivity while the preferred is similar to existing XRS instruments normalized to a peak sensitivity of one.

Wavelength (nm)	XRS Short Channel			XRS Long Channel		
	Preferred	Upper Limit	Lower Limit	Preferred	Upper Limit	Lower Limit
0.04	0.05	.016	0.02			
0.08	0.32	0.44	0.23	0.14	0.28	0.07
0.12	0.71	0.88	0.56	0.37	0.53	0.26
0.16	0.96	1.17	0.78	0.65	0.83	0.48
0.20	1.00	1.21	0.81	0.87	1.08	0.67
0.24	0.87	1.04	0.68	0.98	1.21	0.77
0.28	0.57	0.72	0.44	1.00	1.24	0.79
0.32	0.48	0.62	0.36	0.97	1.21	0.77
0.36	0.34	0.45	0.24	0.92	1.13	0.70
0.40	0.22	0.32	0.14	0.62	0.93	0.56
0.44	0.12	0.20	0.05	0.65	0.84	0.49
0.48	0.05	0.15	0.01	0.65	0.84	0.49
0.52	0.03	0.11	0.00	0.62	0.81	0.47
0.56				0.58	0.76	0.42
0.60				0.51	0.69	0.37
0.64				0.44	0.59	0.30
0.68				0.37	0.52	0.25
0.72				0.30	0.45	0.19
0.76				0.24	0.38	0.14
0.80				0.18	0.31	0.09
0.84				0.13	0.26	0.05
0.88				0.10	0.21	0.03
0.92				0.07	0.18	0.01
0.96				0.05	0.15	0.01

6.8 Measurement Accuracy

 The accuracy of the X-ray flux product shall be ±10% with a goal of ±5% of the actual flux for flux values greater than 20 times the minimum measurable flux.

6.9 Electron Environment

The minimum performance of the Solar X-ray and XRS sensors shall not be compromised by the presence of the anticipated worst-case natural electron environment. To allow for the fact that the trapped particle population is not isotropically distributed, a 2% peak-to-peak sinusoidal variation with angle shall be assumed

superimposed on the average electron environment. The representation for the worst-case natural environment assumes isotropic flux with the spectral distribution shown in Table 6.9.

Table 6.9
Assumed Worst-Case Electron Environment

E (MeV)	0.3	0.45	1.05	1.9
$J(>E)$ (p cm^{-2} sec^{-1})	2×10^7	7×10^6	7×10^5	1.5×10^5

6.10 Temporal Resolution

A measurement shall be obtained every 3 sec with a goal of 0.5 seconds.

The data latency shall be no more than 1 second. (TBD).

The time delay between the XRS-A and XRS-B exposures shall be less than 0.1 seconds.

6.11 Spatial Coverage

The instrument shall provide a measurement of the full solar disk and the lower solar atmosphere (Diameter of 40 arc-min centered at sun-center).

6.12 In-flight Calibration

A calibration mode shall be provided by ground command for determining electronic processing gain to an accuracy of 2% for all channels and for verifying basic instrument functionality. This calibration shall be traceable to incident flux through detector preflight calibration. The in-flight calibration shall be both self-terminating and able to be terminated by ground command.

6.13 Pre-flight Calibration

The complete XRS shall be calibrated for sensitivity to X-ray flux at a facility with an X-ray source traceable to the NIST Standard for X-ray calibration. The accuracy of the calibration shall be such as to demonstrate that the X-ray calibrated product shall be within +/-10% (goal 5%) of the actual flux for flux values greater than 20 times the minimum measurable flux.

6.14 Pointing Accuracy and Angular Response

The instrument response, including the combined effect of spacecraft pointing and sensitivity variations across the sensor field-of-view, shall not deviate by more than 5% (goal 2%) for point sources of constant flux within 20 arc-min of the solar disk center.

6.15 Signal to Noise

The signal level shall be such that at minimum (threshold) flux levels, the mean signal shall be greater than the standard deviation of the data (instrumental noise) over a 10 minute interval.

7 EUVS Requirements

7.1 EUVS Overview and Description

Solar EUV radiation is a dominant energy source for the upper atmosphere and the ionizing radiation produces the ionosphere. Solar variability at these wavelengths is one of the primary drivers of thermospheric/ionospheric variability. Uncertainties in the solar EUV flux are a major source of errors in specification and modeling of the thermosphere and ionosphere. To provide adequate knowledge of this ionizing radiation, knowledge of the full EUV spectrum from 5 to 127 nm is required.

7.2 Wavelength Range

Measurements from 5 to 127 nm shall be made with the resolutions defined below.
>   From 5 to 35 nm: 10 nm resolution
>   From 35 to 115 mn: 40 nm resolution
>   From 118 to 127 nm: 10 nm resolution

 Small gaps between bands may be acceptable but the instrument shall either measure 85% of the spectral range or provide a means of estimating the spectral region that is not measured.

7.3 Minimum Sensitivity and Dynamic Range

For each band or spectral element, the minimum observable flux shall be 0.1 times the expected flux under solar minimum (1996) conditions. The maximum observable flux shall be 10 times the expected solar flux under solar maximum (2001) conditions. Estimates of solar flux for these conditions can be obtained using the SOLAR2000 spectral irradiance model (Tobiska et al., J. Atmos. And Sol-Terr. Phys 62, 2000, 1233-1250; http://www.spacewx.com/Docs/JASTP_2000_SOLAR2000.pdf).

7.3.1 Out of Band Rejection

The out-of-band rejection shall be such that < 10% of the observed signal comes from out-of-band for a typical solar spectrum. If the out-of-band signal is greater than 10%, then a means of measuring and tracking this out-of-band signal shall be provided.

7.3.2 Long-term Stability

Over the duration of the mission, the EUVS instrument response shall change by less than 5% (Goal: <2%). If the sensitivity is expected to change by more than 5% during the life of the mission, then a means of measuring and tracking the signal change shall be provided.

7.3.3 Flux Resolution and Response

The maximum size of each step in the flux measurement shall be 0.25% of specified full scale

7.3.4 Wavelength Response

The wavelength response of each channel shall be measured to an accuracy of ±5%. The instrument shall be calibrated at sufficient wavelengths to adequately characterize the wavelength response.

7.3.5 Measurement Accuracy

The accuracy of the EUV flux products shall be within ±10% of the actual flux (Goal: ±5%). The complete EUVS shall be calibrated for sensitivity to EUV flux at a facility with an EUV source traceable to the NIST Standard for EUV calibration.

7.3.6 Signal to Noise

The signal level shall be such that at minimum (threshold) flux levels, the mean signal shall be greater than the standard deviation of the data (instrumental noise) over a 10 minute interval.

7.4 Electron Environment

The minimum performance of the EUV sensor shall not be compromised by the presence of the anticipated worst case natural electron environment. To allow for the fact that the trapped particle population is not isotropically distributed, a 2% peak-to-peak sinusoidal variation with angle shall be assumed superimposed on the average electron environment. The representation for the worst case natural environment assumes isotropic flux with the spectral distribution shown in Table 7.4

Table 7.4
Assumed Worst-Case Electron Environment

E (MeV)	0.3	0.45	1.05	1.9
$J(>E)$ (p cm^{-2} sec^{-1})	2×10^7	7×10^6	7×10^5	1.5×10^5

7.5 Temporal Resolution

A measurement of the solar flux shall be obtained every 30 seconds.

The data latency, from the completion of image integration to the transmission of the last image bit to the spacecraft data bus, shall be no more than 5 seconds. (TBD)

7.6 Spatial Coverage

The instrument shall provide a measurement of flux from the full solar disk and the lower solar atmosphere (Diameter of 40 arc-min centered at sun-center).

7.7 In-flight Calibration

A calibration mode shall be provided by ground command for determining electronic processing gain to an accuracy of 2% and for verifying basic instrument functionality. This calibration shall be traceable to incident flux through detector preflight calibration. The inflight calibration shall be both self-terminating and able to be terminated by ground command.

7.8 Pointing Accuracy and Angular Response

The instrument response, including the combined effect of spacecraft pointing and sensitivity variations across the sensor field-of-view, shall not deviate by more than 5% (goal 2%) for point sources of constant flux within 20 arc-min of the solar disk center.

8 Acronyms

A/D	Analog to Digital
ACA	After Contract Award
AI	Action Items
AIR	Action Item Review
ANSI/ISO	American National Standards Institute / International Organization of Standards
CCP	Contamination Control Plan
CDR	Critical Design Review
cm	centimeter
CME	Coronal Mass Ejection
CMP	Configuration Management Plan
CMS	Configuration Management System
CPU	Central Processing Unit
DEM	Differential Emission Measure
DOORs	Dynamic Object-Oriented Requirements System
ESD	Electro Static Discharge
EUV	Extreme Ultra Violet
EUVS	Extreme Ultraviolet Sensor
FMEA	Failure Modes and Effects Analysis
FMECA	Failure Modes Effects and Criticality Analysis
FMP	Financial Management Plan
FOV	Field of View
FPCCR	Formulation Phase Concept and Cost Review
FTA	Fault Tree Analysis
GIRD	General Interface Requirements Document
GOES	Geostationary Operational Environmental Satellite
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
Hz	Hertz

ICD	Interface Control Document
IR	Infra Red
IV&V	Independent Verification and Validation
K	Kelvin
MAID	Master Action Item Database
MAR	Mission Assurance Requirements
MAT	Mission Allowable Temperature
MeV	Mega Electron Volts
MLI	Multi Layer Insulation
MMD	Mean Mission Duration
MRD	Mission Requirements Document
MTF	Modulation Transfer Function
MTR	Midterm Review
N/A	Not Applicable
NASA	National Aeromautics and Space Adminitration
NIST	National Institute of Standards and Technology
nm	nanometer
NOAA	National Oceanic and Atmoshperic Administration
NOT	Non-Operational Temperature
OAT	Out-gassing Allowable Temperature
OBP	On-Board Processor
PDR	Preliminary Design Review
PMP	Project Management Plan
PORD	Performance and Operational Requirements Document
PR	Progress Review
PRA	Probabilistic Risk Assessment
RA	Recommended Approach
RAM	Random Access Memory
RFA	Request for Action
RFI	Request for Information
RMP	Risk Management Plan
ROM	Read Only Memory
SCOR	Solar Coronagraph
SCOR-GS	SCOR Ground System
SDP	Sowftware Development Plan
SEL	Single Event Latch-up
SEMP	Systems Engineering Management Plan
SEP	Systems Engineering Process
SEU	Single Event Upset
SIS	Solar Imaging Suite
SIS-GS	SIS Ground System
SLOC	Software Lines Of Code
SOW	Statement of Work
SXI	Solar X-Ray Imager
TBD	To Be Determined
TBR	To Be Reviewed
TBS	To Be Specified

TDI	Time Delay and Integration
TRL	Technology Readiness Level
TS	Trade Study
UIID	Unique Instrument Interface Document
UV	Ultra Violet
VP	Verification Plan
WBS	Work Breakdown Structure
XRS	X-Ray Sensor
XUV	Soft X-ray to EUV